Origin of arsenic in the groundwater of the Región Lagunera, México

Luis Felipe Sánchez and Carlos Gutiérrez-Ojeda
Instituto Mexicano de Tecnología del Agua, Paseo Cuauhnáhuac 8532, 62550 Jiutepec Morelos, México

Abstract Since 1962 Mexican agencies have reported health problems in both people and animals related to the consumption of groundwater with elevated arsenic concentrations in the closed basin of the Región Lagunera, northern Mexico. Water is derived mainly from an unconfined alluvial aquifer which represents the main source of drinking water for more than two million people that inhabit the area. Extensive areas of the alluvial aquifer have arsenic concentrations quite above 0.05 mg/l, the Mexican and USEPA Maximum Contaminant Level (MCL) for drinking water (range of 0.003-0.443 mg/l). The presence of arsenic has been related to several potential sources: hydrothermal activity, use of arsenical pesticides, mining activities and sedimentary origin. The study performed in 1990 by the Instituto Mexicano de Tecnología del Agua (IMTA), showed that arsenic is naturally occurring; its most probable source is due to extinct, intrusive hydrothermal activity combined with a sedimentary process.

INTRODUCTION

Within the world literature there are some reports that describe the existence of groundwater contaminated with arsenic. The clinical manifestations reported in those places are similar. The existence of arsenic in the groundwater of the Región Lagunera, identified since 1962 (Quiñones *et al.*, 1979), has caused adverse health effects in both people and animals (García *et al.*, 1991). The problem of water on the region has become more acute in recent years due to the aquifer overexploitation and the regulation of the Nazas and Aguanaval rivers: They have caused groundwater levels declines of more than 100 m in less than 50 years, the disappearance of the Mayrán and Viesca Lagoons and a decline in the groundwater quality.

LOCATION

The Región Lagunera is situated in the central part of northern Mexico (Fig. 1), between 102°40' and 104° W-longitude and between 25°15' and 26°15' N-latitude. It covers a total area of about 12,000 km^2 and has a population of about two million people, of whom 70% are living in urban areas and the rest in rural areas. The cities of Torreón, Gómez Palacio and Lerdo represent the main urban areas.

CLIMATOLOGY

According to the Köppen classification, the Región Lagunera has a very dry climate, semi-warm, with an average temperature in the summer of 25°C (77°F) and 16°C (61°F) in winter. The mean annual precipitation in the area is 221 mm and the rainy season is from June to October. Evaporation is high with its mean annual value reaching 2406 mm, i.e., eleven times the mean annual precipitation.

HYDROGEOLOGY

The granular aquifer extends basically over half of the area and contributes 50% of all the water used. It is an unconfined aquifer formed by the granular material of the Santa Inés Formation, and by the alluvial and lacustrine deposits of sedimentary origin that filled the old bolsons. Gravels, sands, silts and clays coming from the surrounding mountains are part of such deposits. Its transmissivity ranges from 0.007 m^2/s in areas close to the river to 0.0005 m^2/s in the flood plains, while its inferred storage coefficient is about 0.05-0.06. The principal source of recharge are the Nazas River and the infiltration of water from excess irrigation.

Under natural conditions the predominant flow direction was from southwest to northeast (Escolero *et al.*, 1992). The water table ranged from 1,120 meters a.m.s.l. in the surroundings of Torreón and Gómez Palacio, to 1,095 meters a.m.s.l. at the north. Shallow water tables over the whole basin where the rule.

The spectacular development of the region caused radical changes in the aquifer hydrology. By 1986, abstraction was at least three times greater than the recharge and there were more than 4,800 wells present in the area. This overexploitation resulted in a significantly decline in the water table and groundwater quality.

By 1991, the increased well density in the central part of the area, had caused severe changes in the flow directions. The general flow direction was then from the borders of the basin to the areas located within the central portion of the region. An extended cone of depression was formed between the towns of Fco I Madero and Tlahualilo. The minimum water table elevations were at 1,010 meters a.m.s.l. (Fig. 2); depths to the water table ranged from 40 to more than 110 m. Actually, in some areas the water must be pumped from depths greater than 140 m.

IMTA STUDY

The IMTA study performed in 1990, showed that large areas of the Región Lagunera aquifer have arsenic concentrations above the Mexican drinking water standard of 0.05 mg/l (Fig. 3). Arsenic concentrations ranged from 0.003 to 0.443 mg/l (mean of 0.074 mg/l; standard deviation of 0.099). The highest arsenic concentrations are found in the lagoonal deposits located in the northeastern part of the basin, as well as towards the northwestern and southeastern areas. In general, areas with high arsenic concentrations also have high levels of TDS, sulfates, fluorides, chlorides, sodium, boron and lithium, above their respective regulated limits. The study included 95 wells distributed over the whole main aquifer, of which 41% showed concentrations of As above the Mexican drinking water standard.

ARSENIC ORIGIN

The presence of arsenic has been related to several potential sources (IMTA, 1990): hydrothermal activity, use of arsenical pesticides, mining activities and sedimentary origin. The data analysis showed that arsenic is naturally occurring and that its most probable source is due to extinct, intrusive hydrothermal activity combined with a sedimentary process. This assumption was based on the following: (a) high arsenic concentrations are close to extrusive igneous rocks; (b) high arsenic concentrations are observed in areas with high concentrations of boron, lithium, chloride and fluoride (probably they were the result of magmatic cooling); (c) some wells located at the southeast and northwest portion of the area registered high temperatures, strong smell of hydrogen sulfide (H_2S) and elevated arsenic concentrations; (d) arsenic levels tend to increase towards the ex-Lagoon sites and decreases towards the river; and (e) high arsenic concentrations are associated with the oldest waters of the aquifer.

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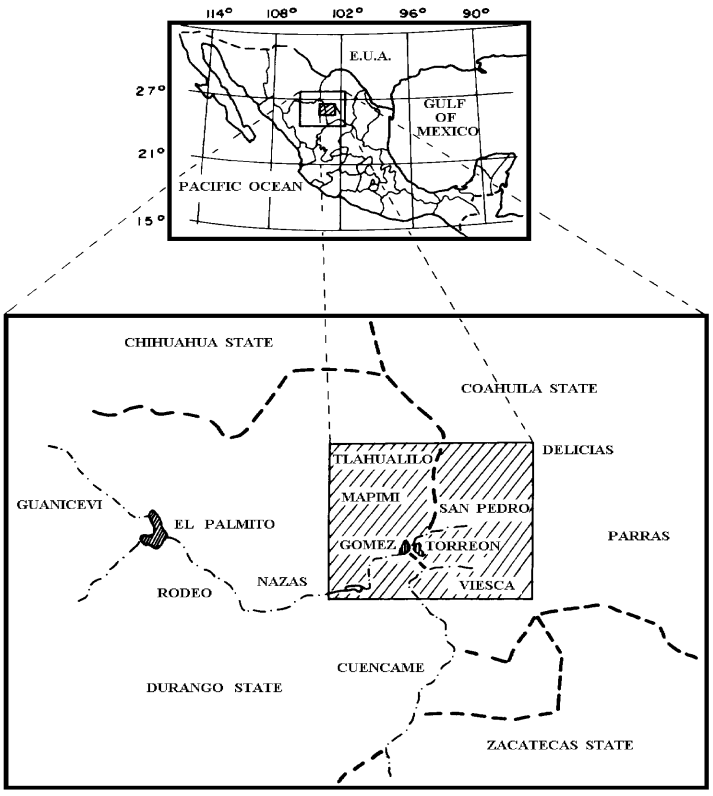

Fig. 1 Geographic location of the Región Lagunera (IMTA, 1990).

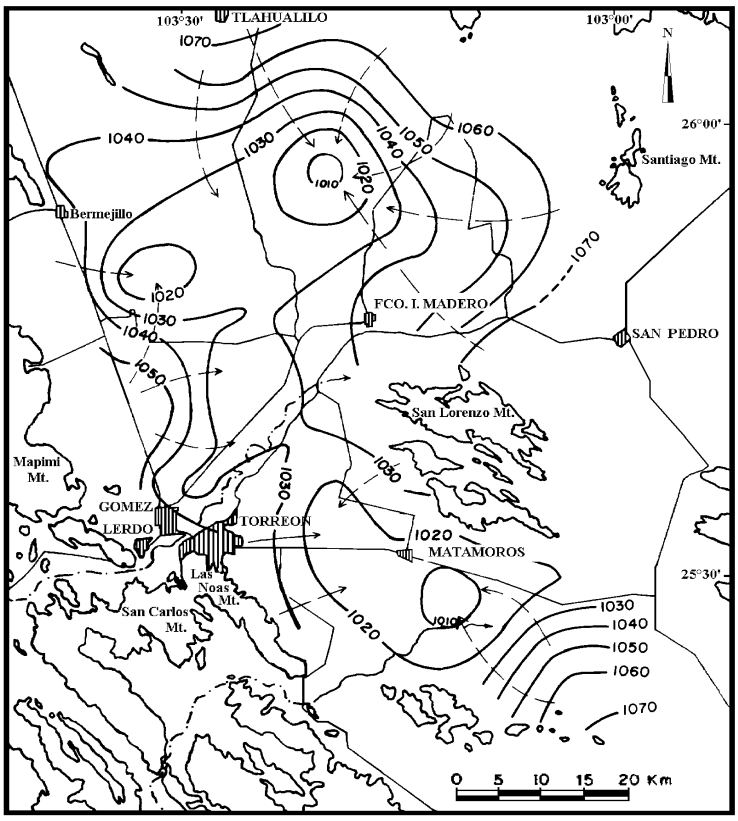

Fig. 2 Water table elevation in 1991 (in meters a.m.s.l.).

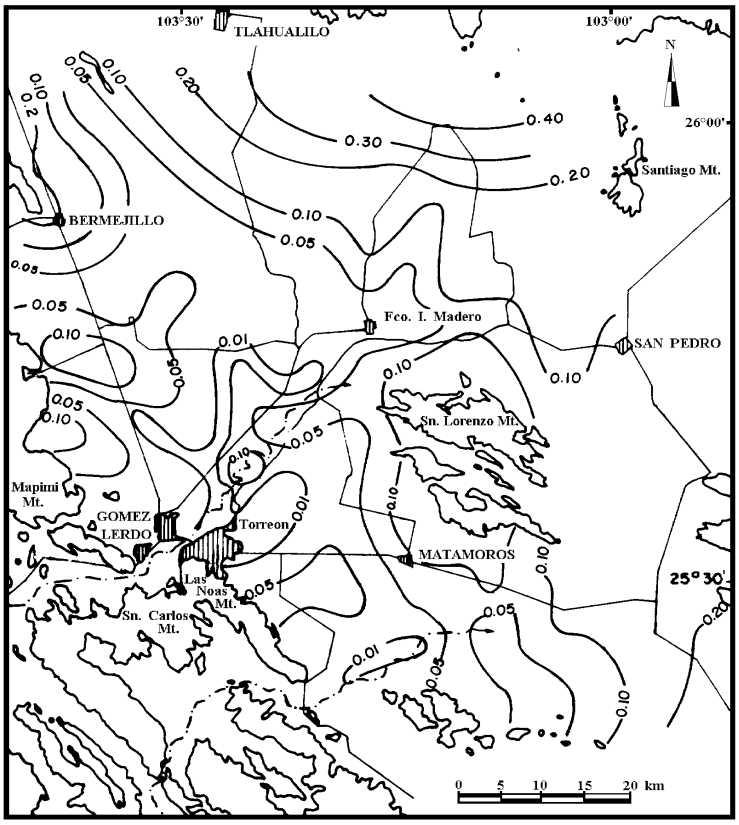

Fig. 3 Total arsenic levels in 1990 (in mg/l).